RESPONSE PURSUANT TO 37 CFR §1.116
EXPEDITED PROCEDURE
GROUP ART UNIT 2816

PATENT
Case No. 11336/108(P00042US)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of)	
)	Group Art Unit: 2816
Gerald R. STANLEY)	
)	Examiner: T. Cunningham
Serial No.: 09/748,609)	
)	
Filed: December 26, 2000)	
)	
For: ACTIVE ISOLATED-INTEGRATOR)	
LOW-PASS FILTER WITH)	
ATTENUATION POLES)	

DECLARATION SUPPORTING RECONSIDERATION OF FINAL REJECTION

I, James Wordinger hereby declare that:

1.   I am an electrical engineer with 24 years of experience in the field of electrical circuit design and electrical circuit operation related to filters and audio power amplifier systems. I graduated from Purdue University in 1979 with a degree in electrical engineering. Upon graduation, I was employed by Crown International as an electrical engineer and have worked as lead engineer on several audio amplifier programs including the MT, MA, CT, MR, K, and CTs amplifier series, representing sales of over $500,000,000 to date. Currently, I am employed by Crown Audio, Inc. a subsidiary of Harman International Industries, Inc. My title is currently Senior Design Engineer. My job responsibilities include product definition, circuit design, analysis, and all aspects of product implementation in a modern team based environment. I am identified as an inventor of D394858 United States patent.

2.   Since 1979 I have worked with about 30 designers, engineers and other technicians who are involved in the design and application of filters and/or audio power amplifier

systems. This experience has provided me with the opportunity to observe others working in this field of endeavor. As a result of this experience, I believe I am well acquainted with a sufficient number of people to assess the skill level of persons of ordinary skill in the art of the design and application of filters and/or audio power amplifier systems.

3.   I have reviewed US Patent Application Serial No. 09/748,609 filed on December 26, 2000 and associated Figures 1 through 5.

4.   I have reviewed the new paragraph that was submitted in the Response to Official Action mailed to the US Patent Office on November 8, 2002.

5.   I have reviewed amended new Figure 6 that it is my understanding will be submitted as part of a Request for Reconsideration that will be filed in response to an Official Action mailed December 23, 2002.

6.   I have reviewed US Patent No. 4,178,556 to Attwood issued on December 11, 1979 that is attached as Exhibit A.

7.   I have reviewed the definition of "feedback" from The Illustrated Dictionary of Electronics, 275 (7th ed., 1997) attached as Exhibit B and concur that the definition is accurate.

8.   I have reviewed the paper entitled "Tunable RC Null Networks," by Ralph Glasgal, from the Oct 1969 issue of EEE, p. 70-74 that is attached as Exhibit C.

9.   I believe that a person of ordinary skill in the art could interpret the disclosure of amended new Figure 6 to be enabled by the existing specification and drawings without undue experimentation based on the following facts:

    a) It is well known to those of ordinary skill in the art to include a feedback control loop to control the operation of a power amplifier system as taught by Exhibit A and B.

    b) It is also well known to those of ordinary skill in the art to include a filter mechanism in a feedback control loop of a power amplifier as further taught by Exhibit A.

    c) It is also well known to those of ordinary skill in the art to provide a feedback signal derived locally at the output of a power amplifier system as taught in Exhibit A, without including an additional feedback signal derived remotely near a load.

d) Those of ordinary skill in the art would understand that paragraph 46 on page 10 describes "another embodiment" of the invention as merely one example of how to practice the invention.

e) Those of ordinary skill in the art would understand that paragraph 46 of page 10 discusses how to remove pulse width modulated (PWM) spectra from the feedback signals using a feedback demodulation filter that includes an isolated-integrator band-reject filter.

f) Those of ordinary skill in the art would understand that paragraph 11 on page 3 and the Abstract of the above-referenced patent application both teach the interconnection of the described components to form a power amplifier system that is illustrated in amended new Figure 6. More specifically:

 1) Those of ordinary skill in the art would understand that paragraph 11 of page 3 describes a power amplifier system that includes a pulse width modulation circuit creating ripple spectra and a feedback control loop coupled to the pulse width modulation circuit.

 2) Those of ordinary skill in the art would understand that paragraph 11 of page 3 also describes that the feedback control loop includes an active low-pass filter having a feedback demodulation filter and an isolated-integrator frequency rejecting network, which is an isolated-integrator band-reject filter in some embodiments.

g) As is well known to those of ordinary skill in the art, and also taught by Exhibits A and B, a feedback control loop provides feedback signals to control an input to a power amplifier system.

h) As is also well-known to those of ordinary skill in the art, ripple spectra (or PWM spectra) as well as other noise in the feedback signals may affect the performance of feedback control.

i) Those of ordinary skill in the art would understand that the feedback demodulation filter when included in the feedback control loop will provide feedback control signals that do not include PWM spectra and can be used to control the input.

j) Those of ordinary skill in the art would understand that if removal of the PWM spectra from a feedback signal is desired, the teachings of the above-referenced patent application teach the addition of the feedback demodulation filter in the feedback control loop to perform this function.

k) Those of ordinary skill in the art would also understand that the above-referenced patent application teaches the addition of the isolated-integrator band-reject filter as part of the feedback demodulation filter.

l) Those of ordinary skill in the art would further understand that neither the paragraph 11 on page 3 nor the abstract teach that an output of the demodulation filter (remote feedback signal) to the feedback control loop is required or essential to the operation of a power amplifier system. This fact is well-known to those of ordinary skill in the art as evidenced by Exhibit A, where a feedback signal is derived locally at the output of the amplifier without an additional remotely derived feedback signal at the load.
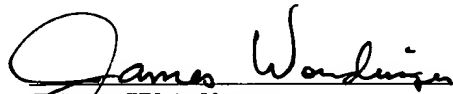
10.   I believe that those of ordinary skill in the art would understand that a power amplifier system that includes in a feedback control loop a feedback demodulation filter having an isolated-integrator band reject filter will operate to control an input to the power amplifier system without an additional feedback signal derived from an output of a demodulation filter.

11.   I believe that those of ordinary skill in the art would understand that the term "isolated-integrator" has the plain meaning which is described in Exhibit C. Further I believe that those of ordinary skill in the art would understand that the special meaning of the term "isolated-integrator" as used in the above-referenced patent application and claims is the same plain meaning described by Exhibit C.

It is my belief that amended new Figure 6 and the new paragraph previously added by amendment are both inherently disclosed by the as-filed patent application, and do not constitute the addition of any new idea or concept.

I hereby declare under penalty of perjury that the foregoing is true and correct.

2/18/03
Date:

                                    James Wordinger

Attachments: Exhibit A (US Patent No. 4,178,556)
               Exhibit B (Electronic Dictionary excerpt - 3 pages)
               Exhibit C ("Tunable RC Null Networks," by Ralph Glasgal, from the Oct 1969 issue of EEE, p. 70-74)

EXHIBIT "A"

U.S. Patent No. 4,178,556

EXHIBIT "B"

Excerpt from

The Illustrated Dictionary of Electronics, 7th Ed. (3 pages)

The
Illustrated Dictionary
of Electronics

Seventh Edition

Stan Gibilisco
Editor-in-Chief

McGraw-Hill

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Caracas Lisbon London Madrid Mexico City Milan
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of bodies and materials to weaken, deform, or fracture under repeated strain.

fault 1. A defective point or region in a circuit or device. 2. A failure in a circuit or device.

fault current 1. A momentary current surge. 2. A leakage current.

fault finder A troubleshooting instrument or device (e.g., a multimeter).

fault resilience 1. A design scheme for an electronic or computer device or system so that if a component or circuit fails, the system will continue to operate, although perhaps at reduced efficiency. The operator is notified of the problem so that it can be repaired with minimal downtime. 2. In a computer-system, the property of being as nearly sabotage-proof as possible.

fault tolerance Total redundancy in an electronic or computer system so that if a component or circuit fails, the system will continue to function at full efficiency. Every component has a backup that automatically takes over in case of failure. The operator is notified of the problem, so the defective part or circuit can be replaced while its backup keeps the circuit working continuously at 100-percent capacity.

Faure plate A storage-battery plate consisting of a lead grid containing a chemical electrolytic paste.

fax Abbreviation of FACSIMILE.

fc Abbreviation of FOOT-CANDLE.

f_c Abbreviation of CARRIER FREQUENCY.

FCC See FEDERAL COMMUNICATIONS COMMISSION.

f_{co} Abbreviation of CUTOFF FREQUENCY.

F connector A type of antenna feedline connection especially common on television receivers and videocassette recorders.

F display See F SCAN.

FDM Abbreviation of *frequency-division multiplex*.

FE Abbreviation of FERROELECTRIC. See FERROELECTRICITY.

Fe Symbol for IRON.

feasibility study The procedures for evaluating the potential gains in applying a computer system to a job or to an organization's process, or in modifying or replacing an existing system.

FEB Abbreviation of FUNCTIONAL ELECTRONIC BLOCK.

Federal Communications Commission Abbreviation, FCC. Established in 1934, the U.S. Government agency that regulates electronic communications. The FCC succeeded the Federal Radio Commission (FRC), which was established in 1927; the FRC succeeded the Radio Division of the Bureau of Navigation in the Department of Commerce, whose jurisdiction over radio began in 1912.

feed 1. To supply power or a signal to a circuit or device. 2. The method of supplying such a signal or power. See, for example, PARALLEL FEED and SERIES FEED. 3. To cause data to be entered into a computer for processing.

feedback 1. The transmission of current or voltage from the output of a circuit or device back to the input, where it interacts with the input signal to modify operation of the device. Feedback is positive when it is in phase with the input, and is negative when it is out of phase. 2. To input the result at one point in a series of operations to another point; the method allows a system to monitor its actions and make necessary corrections.
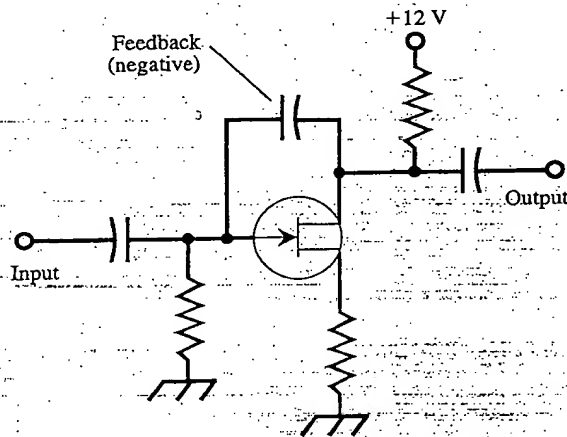
feedback, 1.

feedback amplifier 1. An amplifier whose performance (especially frequency response) is modified by means of positive, negative or both positive and negative feedback. 2. An amplifier placed in the feedback path of another circuit to increase the amplitude of feedback.

feedback attenuation 1. In an operational-amplifier circuit, the attenuation in the voltage from output to input. 2. In an audio-frequency or radio-frequency amplifier circuit, the reduction of feedback by electronic means.

feedback bridge A bridge circuit in the feedback channel of an amplifier or oscillator.

feedback capacitance 1. A capacitance through which feedback current is coupled from the output to the input of a circuit or system. 2. The interelectrode capacitance of a vacuum tube.

feedback control 1. The variable component (potentiometer or variable capacitor) used to adjust the level of feedback current or voltage. 2. The control of circuit performance by means of feedback.

feedback cutter A device used for the purpose of cutting grooves in phonograph disks. Feedback is used to provide a flat frequency response.

feedback factor For a feedback amplifier, the quantity $1 - bA$, where A is the open-loop gain of the amplifier and b is the FEEDBACK RATIO.

EXHIBIT "C"

"TUNABLE RC NULL NETWORKS" By Ralph Glasgal

October 1969 issue of EEE

PGS. 70-74

TUNABLE RC NULL NETWORKS

by Ralph Glasgal

☐ *Some types of RC notch filters (for example, the twin-T) are deservedly popular, whereas other types have been almost completely neglected by circuit designers.*

Author Glasgal takes a second look at some of these less-popular circuits and shows how (unlike the twin-T) a few of them have the advantage that they're easy to adjust. ☐

The advent of linear ICs has awakened new interest in filter circuits that don't need inductors and which can therefore be more easily integrated. More and more circuit designers are now turning to null-producing RC networks as a substitute for LC networks in such circuits as active filters[1] and oscillators.

But, to achieve the versatility of LC circuits, the RC networks must be readily adjustable. Capacitors can't be easily adjusted over a wide range — either mechanically or electronically. For these reasons, we are forced to vary the resistive components of RC networks, just as we usually vary the inductors in conventional LC circuits.

In this article, we will look at the schematics and transfer functions of all the easily-tunable six-element RC networks that have a common ground for input and output (i.e. three-terminal networks).

Some of these networks can be adjusted by changing only a single resistor. These networks are well suited for electronic frequency control.

Other networks can be adjusted by changing the ratio of two adjacent resistors, using a potentiometer. These circuits are better suited for servo or mechanical-control applications.

Eight-element ladder

Let's look first at the eight-element ladder network. An understanding of the theory[2] and

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Author: Mr. Glasgal is now a consultant in New York City. When he wrote this article he was a Design Engineer with Siemens AG in Munich, West Germany.

properties of this network will help us to understand the properties of the six-element networks that are related to it.

The eight-element network is shown in Fig. 1. Its properties can be explained qualitatively, without resorting to mathematical equations. For simplicity, we will assume that the emitter followers have infinite input impedance and zero output impedance.

Phase shifts, in the two halves of the network, are in opposite directions. If all the R's and all the C's are equal, the phase difference between voltage e_a and e_b is always 180 degrees regardless of the frequency.

But, as the frequency varies, the amplitudes of e_a and e_b change. One increases proportionately while the other decreases. The two are only equal when the absolute phase shifts of e_a and e_b are each 90 degrees.

Since the phase difference between e_a and e_b is always 180 degrees, and since $e_a + e_b$ is always constant, we can always find a point on the potentiometer where the two voltages cancel, whatever the frequency.

Conversely, we can adjust the potentiometer setting to determine the null frequency. If we set the numerator of the transfer function equal to zero, we can derive an equation relating the null frequency to the potentiometer setting.

Though this network offers a wide range of frequency adjustment with a single potentiometer, it has several disadvantages.

One disadvantage is its complexity. It consists of eight RC elements plus an additional potentiometer. The emitter followers, however, are not absolutely essential.

Another disadvantage is the inherent insertion loss of at least 6 dB on both sides of the notch region. We can see (from the transfer equation) that, with the potentiometer at the mid setting, $e_{out}/e_{in} = 0.5$. For any setting of the potentiometer other than the middle, attenuation is not symmetrical about the null frequency.

Yet another problem, related to the problem of asymmetry, is the nature of the phase response. Though the phase of the output signal

Simple filter circuits that can be tuned by adjusting a single resistor or potentiometer.
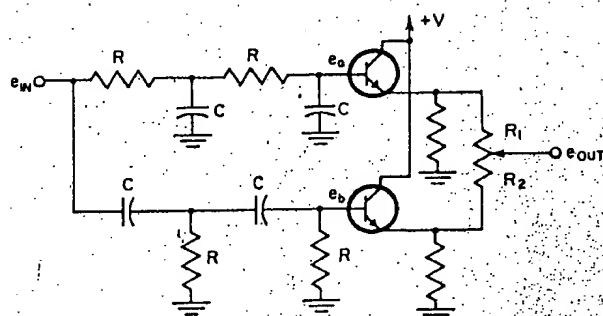
$$y = \frac{R_1}{R_1 + R_2} \qquad x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{1 - y - yx^2}{1 + 3jx - x^2}$$

$$f_{null} = \frac{1}{2\pi RC}\sqrt{\frac{1-y}{y}}$$

$$\phi_{null} = \pm \tan^{-1}\frac{3\left(\frac{1-y}{y}\right)^{1/2}}{1 - \left(\frac{1-y}{y}\right)}$$
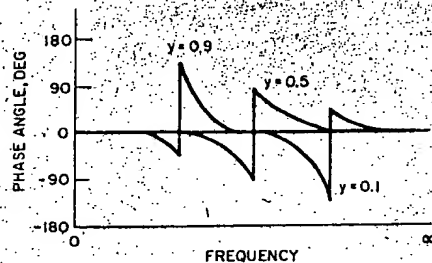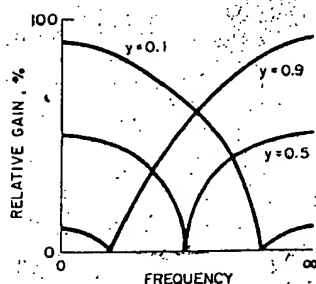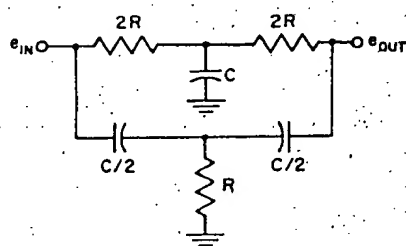
Fig. 1A. Tunable eight-element ladder network.

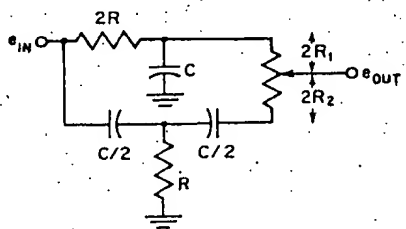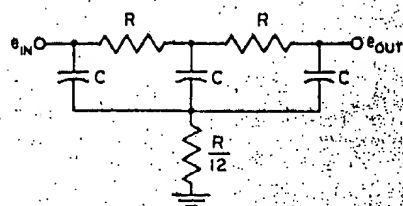Fig. 1B. Transfer characteristics of the eight-element ladder.

Fig. 2A. Basic twin-T null network is derived from the ladder network.

$$x = 2\pi fCR$$

$$\frac{e_{out}}{e_{in}} = \frac{1 - x^2}{1 + 4jx - x^2}$$

$$f_{null} = \frac{1}{2\pi CR}$$

Fig. 2B. Twin-T cannot be tuned in the same way as the ladder network. A potentiometer, connected as shown, doesn't provide useful adjustment.

$$y = \frac{R_1}{R_1 + R_2}$$

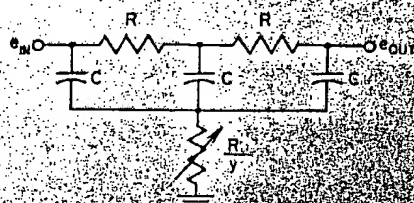$$\frac{e_{out}}{e_{in}} = \frac{1 - x^2 + jyx - yx^2}{1 + 4jx - x^2}$$

$$x = 2\pi f RC$$

$$\frac{e_{out}}{e_{in}} = \frac{12 + 3jx - 4x^2 - jx^3}{12 + 39jx - 16x^2 - jx^3}$$

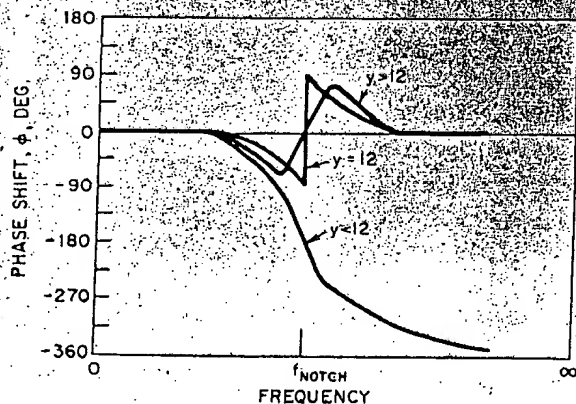$$f_{null} = \frac{\sqrt{3}}{2\pi RC}$$

Fig. 3A. Basic isolated-integrator network.

$$\frac{e_{out}}{e_{in}} = \frac{y + 3jx - 4x^2 - jx^3}{y + 3(1 + y)jx - (4 + y)x^2 - jx^3}$$

$$f_{notch} \cong \frac{1}{2\pi RC}\left(\sqrt{\frac{73 + 24y}{9} - \frac{10}{3}}\right)^{1/2}$$

Fig. 3B. Tunable isolated-integrator can be adjusted by varying a single resistor. Note that one end of the resistor is grounded.

$$\phi = tan^{-1}\frac{3x - x^3}{y - 4x^2} - tan^{-1}\frac{3x(1 + y) - x^3}{y - (4 + y)x^2}$$

Fig. 3C. Phase response of tunable isolated-integrator for various potentiometer settings.

always shifts instantaneously by 180 degrees, as frequency crosses the null frequency, the exact form of the phase response depends on the potentiometer setting.

Typical phase-response curves are shown in Fig. 1B. When $y = 0.5$, the relative phase angle (between output and input) changes abruptly from $+90$ to -90 degrees. But, for other settings of the potentiometer (i.e. for other values of y), the phase could jump from $+135$ to -45 degrees, or from $+45$ to -135 degrees, as shown. In fact, the phase could jump between any two phase angles that are 180 degrees apart and which lie within the region $+179$ to -179 degrees.

For the networks considered here, we will find in general that the instantaneous 180-degree phase change occurs only in those cases where the notch attenuation is truly infinite. For those filters with finite notch attenuation, the phase curve in the region of the notch frequency will not have infinite slope — neither will it span a full 180 degrees.

Twin-T null network

The well-known twin-T network is shown in Fig. 2A. We can see at a glance that it closely resembles the ladder network of Fig. 1. The twin-T circuit saves one resistor and one capacitor because, in each half of the circuit, the opposite T section replaces the fourth element of the ladder chain.

Based on our experience with the circuit of Fig. 1, we might suppose that we could tune the twin-T with a potentiometer as shown in Fig. 2B. But, in practice, this proves to be a very poor technique. The notch frequency shifts only a small amount with large changes in potentiometer setting. Also, the circuit gives large residual notch voltages and has asymmetric attenuation and phase characteristics.

Fortunately there are four other null-generating six-element networks that we can choose from. Later we will see that three of these networks are more easily adjustable than the twin-T.

Schematics of the three adjustable networks are shown in Figs. 3, 4 and 5, along with their design equations. Fig. 6 shows two other configurations that one might be tempted to use but which provide no simple tuning method.

For want of better names for the various six-element networks, let's follow the example of Van Emden[3] and call the circuit of Fig. 3 an "isolated integrator." Then we can refer to the other networks as the "isolated differentiator" (Fig. 4), the "bridged differentiator" (Fig. 5), and the "bridged integrator" (Fig. 6B).

When we start to look at the tunability of these networks, we can quickly dispose of the bridged integrator. With the circuit of Fig. 6B, as with the twin-T, it is impossible to vary the resistors and still retain a good notch. Also, there is no potentiometer setting that gives a symmetrical response curve.
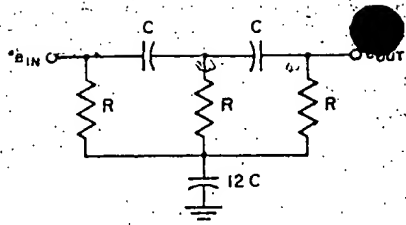
$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 3x^2 - 12jx^3}{1 + 16jx - 39x^2 - 12jx^3}$$

$$f_{null} = \frac{1}{2\pi RC\sqrt{3}} \qquad x = 2\pi fCR$$
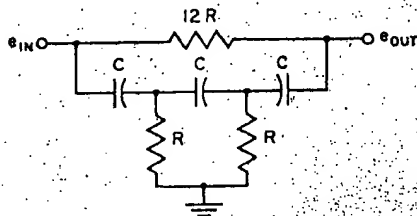
Fig. 4A. Basic isolated-differentiator network.
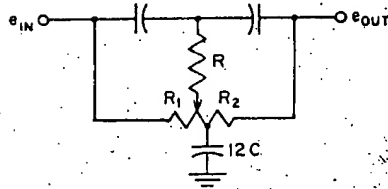
$$y = \frac{R_1}{R_1 + R_2}$$

$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 2x^2 - 4(y - y^2)x^2 - 48j(y - y^2)x^3}{1 + 4jx + 24yjx - 2x^2 - 100yx^2 - 52y^2x^2 - 48(y - y^2)jx^3}$$

$$f_{notch} = \frac{1}{2\pi RC}\left(\frac{1}{4 + 8y - 8y^2} + \frac{1}{24(y - y^2)}\right)^{1/2}$$

Fig. 4B. With a potentiometer connected as shown, notch frequency of the isolated differentiator can only be adjusted over a range of a few percent.
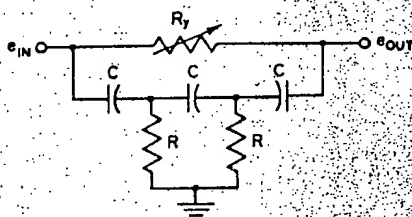

$$x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 3x^2 - 12jx^3}{1 + 16jx - 39x^2 - 12jx^3}$$

$$f_{null} = \frac{1}{2\pi RC\sqrt{3}}$$
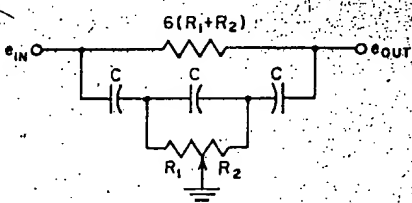
Fig. 5A. Basic bridged-differentiator network.

Fig. 5B. Resistor-tuned bridged differentiator. A disadvantage of this circuit is that neither end of the tuning resistor can be grounded.

$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 3x^2 - yjx^3}{1 + (4 + y)jx - 3(1 + y)x^2 - yjx^3}$$

$$f_{notch} \simeq \frac{1}{2\pi RC}\left(\frac{8}{3y} - \frac{3}{y^2} + \frac{1}{y}\sqrt{\frac{9}{y^2} + \frac{34}{9} - \frac{16}{y}}\right)^{1/2}$$

$$y = \frac{R_1}{R_1 + R_2} \qquad x = 2\pi f(R_1 + R_2)C$$

$$\frac{e_{out}}{e_{in}} = \frac{1 + 2jx - 3(y - y^2)x^2 - 6(y - y^2)jx^3}{1 + 16yx - 3(2 - y^2 + 3y)x^2 - 6(y - y^2)jx^3}$$

$$f_{null} = \frac{1}{2\pi C\sqrt{3R_1R_2}}$$

Fig. 5C. Potentiometer-tuned bridged differentiator. Regardless of the potentiometer setting, this network always gives infinite attenuation at the null.
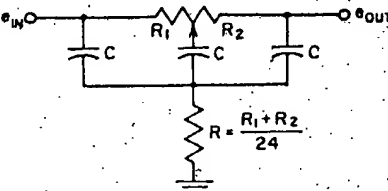
$$y = \frac{R_1}{R_1 + R_2} \qquad x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{1 + 3jx - 48x^2 - (24)^2(y - y^2)jx^3}{1 + 27jx + 24yjx - 48x^2 - (24)^2(y - y^2)x^2 - (24)^2(y - y^2)jx^3}$$

$$f_{null} = \frac{1}{\sqrt{48}\ 2\pi RC}$$

Fig. 6A. One might be tempted to try this method of adjusting the isolated integrator. But the potentiometer has absolutely no effect on the null frequency.
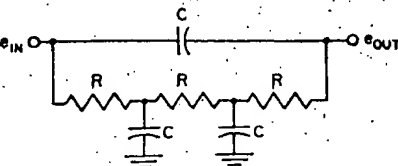
$$x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{12 + 3jx - 4x^2 - jx^3}{12 + 39xj - 16x^2 - jx^3}$$

$$f_{null} = \frac{\sqrt{3}}{2\pi RC}$$

Fig. 6B. Basic bridged-integrator network is shown here for completeness only. This network offers no convenient tuning method.

One special advantage of the isolated integrator, shown in Fig. 3, is that its notch frequency is easily adjusted in both directions by means of a single variable resistor. So, the circuit can be adjusted remotely and electronically, using devices such as photoresistors, thermistors and nonlinear diodes.

Sensitivity of the frequency adjustment is quite high. A resistance change of 10 percent gives a notch-frequency variation of about 3.5 percent. Attenuation is always symmetrical on both sides of the notch — provided source and load impedance are negligible.

But the circuit of Fig. 3B does have several disadvantages. An infinite-attenuation notch can only be achieved with one value of R/y. If the resistance is adjusted too far from this optimum value, the notch becomes too shallow for most applications.

Another disadvantage of the isolated integrator is that phase response depends on the value of R/y. For low values of R/y, the phase angle is always negative as shown in Fig. 3C. But, when R/y is large, the phase angle does reverse from a negative angle through zero to a positive angle.

One other possible disadvantage is that the values of the capacitive elements are larger than in an equivalent twin-T network. From the equations we find that the capacitors are larger by a factor of $\sqrt{3}$. This makes the isolated integrator less suitable for fabrication in IC form.

Another possible configuration for the isolated integrator is shown in Fig. 6A. This arrangement has little or no practical value and is shown here merely to complete the list of possibilities. Rotating the potentiometer produces absolutely no change in the notch frequency.

Isolated differentiator

One network that can be tuned by a potentiometer is shown in Fig. 4B. This circuit is a variation of the isolated differentiator shown in Fig. 4A.

Unfortunately, with this circuit, frequency adjustment is very insensitive. The first 20-percent shift of the potentiometer in either direction from its mid point produces a frequency shift of less than 2 percent.

Also, the depth of the null is adversely affected by variations in potentiometer setting, as was the case with the isolated integrator circuit. But, in those applications where we need very fine tuning (say a few Hz per kHz), this network could be useful.

Bridged differentiator

The bridged differentiator, shown in Fig. 5A, can be adjusted in two ways. It can either be tuned with a variable resistor as shown in Fig. 5B, or with a potentiometer as in Fig. 5C.

With single-resistor adjustment (Fig. 5B), the network behaves much like the isolated integrator, in that the depth of the notch decreases as the resistor is varied from its nominal value R/y. But this type of bridged differentiator has the added disadvantage that neither end of the tuning resistor is at ground potential. So this circuit is probably not as widely useful as the isolated integrator.

But, when we examine the behavior of the potentiometer-tuned version (Fig. 5C), we get a pleasant surprise.

With this network, the depth of the notch remains infinite while the notch frequency can be varied over a wide range. Sensitivity increases parabolically with y as the notch frequency is increased unidirectionally from a minimum value.

The phase response is stable, too. Relative phase hovers about 90 degrees, in the vicinity of the null, and changes only slightly with the setting of the potentiometer.

One disadvantage is that the attenuation curve is not symmetrical, except when the potentiometer is in its mid position. Even with a low-source impedance, the filter behaves more and more like a low-pass filter as the frequency increases. This is the same problem that arose with the eight-element ladder network.

Which network?

The principal advantages and disadvantages of each of the networks are summarized in the table. Probably the most useful network, for control by a single variable resistor is the isolated integrator. The fact that one leg of the variable resistor can be grounded makes this network especially attractive. The resistor can easily be replaced by various types of transducer elements for automatic control.

On the other hand, where complete rejection at the null frequency is imperative, and where mechanical adjustment is feasible, then the bridged differentiator is probably the best choice. EEE

COMPARISON OF RC NULL NETWORKS

Network type	Tunable with single variable resistors?	Tunable with single pot?	Is variable element grounded?	Is null rejection infinite?	Control sensitivity	Is attenuation symmetrical?
Eight-element ladder	No	Yes	No	Yes	High	No
Twin T	No	No	—	—	—	—
Bridged integrator	No	No	—	—	—	—
Isolated integrator	Yes	No	Yes	No	High	Yes
Isolated differentiator	No	Yes	No	No	Low	Yes
Bridged differentiator	Yes		No	No	High	Yes
Bridged differentiator		Yes	Yes	Yes	Med.	No

References

1. T. Mollinga, "Active Parallel-T Networks," EEE, April 1966.
2. W. K. Clothier, "Resistance-Capacitance Filter Network with Single-Component Frequency Control," IRE Transactions on Circuit Theory, Vol. CT-2, No. 1, March 1955.
3. B. M. Van Emden, "The Isolated-Integrator Network," EEE, May 1964.
4. H. P. Hall, "RC Network with Single-Component Frequency Control," IRE Transactions on Circuit Theory, Vol. CT-2, No. 3, September 1955.